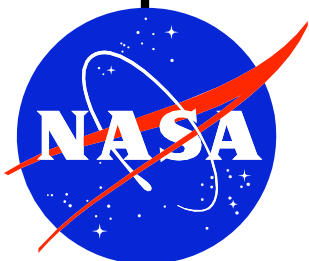# GAMMA-RAY LARGE AREA SPACE TELESCOPE (GLAST)

GROUND SYSTEM

IMPLEMENTATION PLAN

July 16, 2004

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

433-PLAN-0016

GAMMA-RAY LARGE AREA SPACE TELESCOPE
(GLAST)
PROJECT

GROUND SYSTEM IMPLEMENTATION PLAN

Final – July 16, 2004

NASA Goddard Space Flight Center

Greenbelt, Maryland

DOCUMENT APPROVAL
GLAST GROUND SYSTEM IMPLEMENTATION PLAN
July 2004

Prepared by:

_____   Date
Ernest V. Canevari
ASRC Aerospace
System Engineer

Concurrence:

_____   Date
Dennis Small
MOC

_____   Date
Doug Spiegel
MOC

_____   Date
Jay Norris
GSSC

_____   Date
Bill Craig (Acting)
LAT ISOC/DPF

_____   Date
Richard Dubois
LAT ISOC/SAS

_____   Date
William Paciesas
GBM IOC

_____   Date
Leslie Ambrose
Customer Commitment Manager

Approved by:

_____   Date
Ken Lehtonen
GLAST Ground System/Ops Manager

_____   Date
Kevin Grady
GLAST Project Manager

REVISION STATUS

The GLAST Ground System Configuration Control Board (CCB) controls this document. Proposed changes shall be submitted to the GLAST Ground System and Operations CCB for approval.

VERSION	DATE	CHANGED BY	DESCRIPTION

OPEN ITEMS

This table lists the items that remain open as of the publication of this version of the document. As they are closed the resolutions will be incorporated into the body of the document.

ISSUE #	AFFECTED AREA	DESCRIPTION

OPEN ACTIONS

This table lists the action items that remain open as of the publication of this version of the document. As they are closed the resolutions will be incorporated into the body of the document.

ACTION #	ACTIONEE	DESCRIPTION

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1.0   INTRODUCTION

1.1   Purpose

The purpose of this document (also referred to herein as the Plan) is to describe the management approach associated with implementing the GLAST Ground System and to ensure that the implementation effort is compliant with ISO (International Organization for Standards) 9000 standards. A team of personnel within and outside of NASA Goddard is developing the GLAST Ground System. Section 2 provides a description of the Ground System elements and the approach being used for development. The remaining sections then provide a description of how the development of the GLAST Ground System will be managed. They will address the following items:

- Development Organization and Approach
- Configuration and Risk Management
- IT Security
- Test Approach
- Discrepancy Management Approach

1.2   Scope

This Project Plan addresses the approach to implementing the GLAST ground system. It thus applies to the development and testing of the system, but not the activities associated with preparing for mission or science operations. The latter will be addressed in the *GLAST Mission Operations Agreement Roles and Responsibilities* (MOA) and in the *GLAST Mission Operations Readiness Plan*, both of which will be developed to describe the approach to achieving readiness for operations and the associated roles and responsibilities of the mission operations personnel.

While some overview information is given in Section 2, this Plan does not include detailed descriptions of (1) the mission science goals or plans, (2) ground system, spacecraft or instrument architecture/design, or (3) overall mission operations concepts and scenarios. These areas are referenced in the GLAST documents listed in section 1.3. It is assumed that the reader of this Plan is already familiar with these topics for the GLAST mission and that they thus do not need to be addressed here.

This Plan is controlled and managed by the GLAST Project CCB (Configuration Control Board).

1.3   Mapping to Ground System MAR

The Ground System Mission Assurance Requirements (MAR) document serves as an agreement between the GLAST Ground System/Operations Manager (GSOM) and the Systems Management Office (Code 300) on how the Ground System implementation will be managed. It is thus similar in scope to this Project Plan. The MAR document uses some terminology that carries heritage from previous Code 300 quality assurance efforts, which traditionally are more oriented to the spacecraft and instrument areas. This section provides a mapping between the MAR terminology and the terminology more traditionally used by ground systems (and thus used in this Plan). This will help to illustrate how the Ground System implementation plan

described in this document satisfies the requirements defined in the GLAST Ground System MAR document.

- The Performance Assurance Implementation Plan (PAIP) (DID A) - covered by this *Ground System Implementation Plan*.

- Quality Manual (DID B) - will not be provided by the Ground System.

- Quality Assurance Plan (DID C) - covered by this *Ground System Implementation Plan*.

- Software Development Plan (DID D) - covered by this *Ground System Implementation Plan* and in each *element's Development Plan*.

- GDS Requirements (DID E) - covered by the *Ground System Requirements Document* (GSRD) and the *Ground System Requirements Verification Matrix*.

- GDS Review Packages (DID F) - the Ground System will conduct SRR, MOR, and ORR. Requirements for the PDR and CDR will be met by element level Peer Reviews and a Ground System Design Review.

- Ground Ops Procedures (DID G) – operations descriptions will be developed and delivered by spacecraft contractor, instrument teams and flight operations team. The Flight Operations Team will develop executable PROCs.

- System Performance Verification Plan (DID H) – covered by the *Ground System Test Plan* and the *Ground System Requirements Verification Matrix*.

- Performance Verification Procedure (DID I) – covered by the Ground System Test Scripts.

- Verification Report (DID J) - covered by the Ground System Test Reports.

- Data Delivery Packages (DID K) – covered by delivery package provided by each element of the Ground System.

- Risk Management Plan (DID L) – risks associated with the Ground System implementation and test process are covered by this *Ground System Implementation Plan*. The IT Security Risk Management Plan will cover risks associated with the Ground System facilities.

- Software Configuration Management Plan (DID M) – covered by each element's *Development Plan* or *Configuration Management Plan*.

1.4   Team Charter

The GLAST Ground System development team is responsible for requirements development, systems engineering, design, implementation, system integration, and testing of the GLAST Ground System. In addition, the Ground System team will maintain configuration and quality control and manage a ground system schedule. The Ground System team will lead or support, as appropriate, the definition and documentation of internal and external interfaces. The team shall complete the Ground System development in order to support the launch of the GLAST observatory, scheduled for launch in February 2007.

1.5   Customer Identification

The primary customer for the products and capabilities developed by the GLAST Ground System team is the GLAST Project Scientist.

1.6   Customer Goals and Objectives

The main customer's objectives for the GLAST Ground System development team are to build a ground system for the GLAST mission that provides the appropriate capabilities to:
   o monitor, control and maintain observatory health and safety,
   o activate and check-out the spacecraft and instruments after launch,
   o perform observation planning activities,
   o capture, process and distribute observatory data.

1.7   Applicable Documentation

The following documents provide information that is applicable to this Plan. In case of conflicting requirements or statements with this Plan, the information provided in the applicable documents takes precedence.

   1.   "GLAST Project Plan", 433-PLAN-0001
   2.   "GLAST Science Requirements Document", 433-SRD-0001
   3.   "GLAST Mission System Specification Document", 433-SPEC-0001
   4.   "GLAST Ground System Requirements Document", 433-RQMT-0006
   5.   "GLAST Ground System Mission Assurance Requirements Document", 433-MAR-0004

1.8   Reference Documentation

The following documents and material provide reference information to help provide context for this document. They are for reference only and do not take precedence over this Plan.

   1.   "GLAST Project Mission Operations Concept Document", 433-OPS-0001
   2.   "GLAST Ground System Requirements Review Presentation", July 22, 2003

2.0   GLAST GROUND SYSTEM OVERVIEW

The GLAST Ground System is being developed to provide mission and science operations support to the GLAST mission. GLAST is scheduled for launch in February 2007. The GLAST Ground System is scheduled to be operationally ready no later than 60 days before launch.

The Large Area Telescope (LAT) and GLAST Burst Monitor (GBM) instruments will satisfy the GLAST mission science objectives. The primary instrument, the LAT, will have superior area, angular resolution, field of view, and dead time. LAT will detect gamma-ray energies of 20 million eVs to greater than 300 billion eVs. The GBM will have a field of view several times larger than that of the LAT and will provide spectral coverage of gamma-ray bursts that extends from the lower limit of the LAT down to 10 keV. The LAT will provide advanced sensitivity by a factor of 30 or more than previous missions as well as the capability to study transient phenomena. These instruments will provide the GLAST observatory the flexibility to investigate the great range of astrophysical phenomena best studied in high-energy gamma rays.

The GLAST Ground System shall support highly autonomous mission operations that will allow lights out operations with only prime shift flight operations support. The Ground System will conduct automated spacecraft operations, data handling and processing, telemetry monitoring, and alarm detection. The automated monitoring will allow the Flight Operations team (FOT) to conduct all nominal operations using daily 8-5 shifts Mondays through Fridays. The Ground System will alert the FOT to any spacecraft or ground anomalies, which will require operator intervention.

In addition, the Ground System shall provide processed (Level-1) data products to users from the Level-0 data within 72-hours of initial detection on board by the instruments. Burst Alert Messages will be autonomously generated by the observatory and reach the Gamma Ray Burst Coordinate Network (GCN) within 7 seconds after a burst is detected. The GCN will distribute notices to observers around the world.

The system shall also support science observation planning and scheduling. The system shall respond to a Target of Opportunity order within 6 hours of Project Scientist approval.

The GLAST Ground System is comprised of the following elements:

Element	Lead	Location
Commercial Ground Station	USN	Hawaii (South Point), Australia (Dongara)
Space Network (TDRS, WSC, DSMC)	Code 450	Goddard Space Flight Center (GSFC)
MOC/Flight Operations	Goldbelt Orca/Omitron	GSFC
GLAST Science Support Center (GSSC)	Code 600	GSFC
LAT Instrument Science and Operations Center (LISOC)	Stanford Linear Accelerator Center (SLAC)	Palo Alto, CA

Element	Lead	Location
GBM Instrument Operations Center (GIOC)	Marshall Space Flight Center/ University of Alabama	NSSTC/Huntsville AL
HEASARC	Code 600	GSFC
GRB Coordinates Network (GCN)	Code 600	GSFC
Flight Dynamics Facility (FDF)	Code 590	GSFC
Spacecraft (dev/I&T/ops)	Spectrum Astro Incorporated (SAI)	Gilbert, AZ
Ground Communications Network	Goldbelt Orca/Omitron, NISN, Code 660	N/A
Launch Site	NASA	Kennedy Space Center (KSC)

The Ground System architecture is shown below in Figure 2-1.
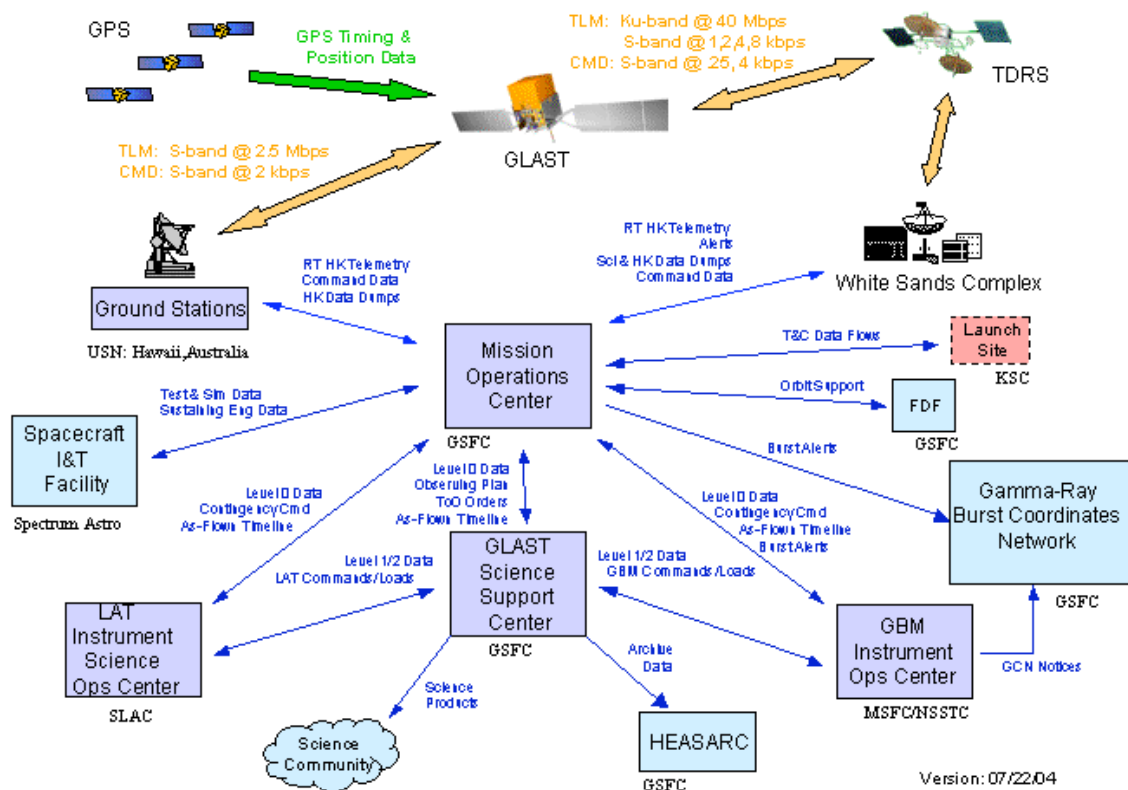
Figure 2-1: GLAST Ground System Architecture

The sections that follow provide a brief description of each ground system element.

2.1   Space Network (SN)

The Space Network (SN) is an existing NASA institutional space communications system that consists of a collection of Tracking and Data Relay Satellites (TDRSs), the White Sands Complex (WSC) in New Mexico, and the Data Service Management Center (DSMC). The SN will provide GLAST with the primary means of command and science data collection. GLAST will be supported by both the first generation (pre-TDRS-H) and second-generation (TDRS-H, I & J) sets of TDRS satellites. The SN will provide Multiple Access (MA) services and Single Access (SA) services for the GLAST mission.

The scheduled legacy and Demand Access Service (DAS) MA services will be provided. The legacy MA services, which are scheduled as needed, provide S-Band 0.25 kbps forward link and 1 kbps return link service. DAS provides near continuous MA S-band downlink coverage for low rate housekeeping telemetry and Gamma Ray Burst (GRB) alerts. This provides the ability for the spacecraft to initiate S-band downlink communication with the Ground System when needed at 1 kbps (e.g., On-board anomaly detection, L&EO, Burst Alert Messages).

The scheduled SA services will provide 4 kbps forward link S-Band, up to 8 kbps S-Band return link and 40 Mbps return link Ku-Band services. The Ku-Band service will be used as the primary mechanism for downlinking real-time Housekeeping data, recorded Housekeeping data, and recorded Science data. The real-time data can also include alert, alarm, and diagnostic telemetry.

The White Sands Complex, located in New Mexico, is the facility that uplinks and downlinks commands and data to and from the TDRS satellites and interfaces with the Mission Operations Center (MOC).

The Data Services Management Center, located at WSC, is responsible for scheduling the use of TDRS services through the Satellite Web-based Scheduling Interface (SWSI). The MOC will use the Web-based SWSI interface to schedule use of the legacy MA/SA services. The DSMC will automatically schedule use of the TDRS satellites for support of the DAS and provide the TDRS allocation scheduled to the MOC via the SWSI. Due to the narrow beam width nature of the Ku band and the location of the Ku Band antenna on the spacecraft, the MOC will schedule TDRS contacts based on predicted GLAST observatory attitude.

2.2   Ground Network

The ground network provides S-Band space-to-ground communications (only) to supplement coverage provided by the Space Network. The Ground Network is comprised of the Universal Space Network (USN), described below.

2.2.1   Commercial Ground Station (USN)

Universal Space Network (USN) has commercial sites available in South Point Hawaii and Dongara, Australia.   The sites could support simultaneous S-band return link science data acquisition at 2.5 Mbps (including burst alert messages) and S-band forward link command functions at 2 kbps.

The USN ground stations are also capable of:

- forwarding commands received from the MOC to the observatory,
- receiving observatory real-time housekeeping data and forwarding to the MOC in real-time,
- receiving and recording S-band observatory dump data, and forwarding the dump data to the MOC after each contact.

2.3 Mission Operations Center (MOC)

The Mission Operations Center, located at the Goddard Space Flight Center (GSFC), Greenbelt, MD, will operate the GLAST observatory. It supports pre-launch, launch, early orbit activation, normal, and contingency operations. The MOC serves as the single point of observatory commanding for the Ground System. The MOC performs spacecraft and instrument mission planning, monitoring, and Level-0 data processing. The processed data is made available to the GLAST Science Support Center (GSSC) and Instrument Operations Centers (LISOC and GIOC). The MOC provides rapid response for the follow-up of new GRBs detected by the observatory, and Targets of Opportunity (ToO) inputs from the science team or science community.

Goldbelt Orca/Omitron is responsible for implementing the MOC and providing the Flight Operations Team (FOT). The MOC design is based on the Swift architecture. For example, both utilize the Integrated Test and Operations System (ITOS), a Goddard-provided command and control system that is being successfully used on other GSFC programs such as the Small Explorer Program (SMEX). The GLAST MOC will re-use significant portions of the Swift MOC planning and offline analysis systems.

2.4 GLAST Science Support Center (GSSC)

Located at the Laboratory for High Energy Astrophysics (LHEA) (Code 660) at GSFC, the Science Support Center is the interface between the GLAST mission and the scientific community. The GSSC will provide GLAST data, analysis software and documentation to users, and will support the Guest Investigator (GI) program through the NASA Research Announcement process, organizing the peer-review process, and assisting investigators in data analysis. The GSSC will ingest the Level 1/2 data from the IOCs, store them in its online databases, and transfer these data to the HEASARC as the permanent mission archive. The GSSC will also maintain the science timeline, which will be based on accepted GI proposals and the requests of the IOCs. The GSSC will evaluate instrument commands passed from the IOCs to their instruments in order to assess the potential impact of the commands on the science timeline. The GSSC will pass the instrument commands to the MOC for load generation and execution. The GSSC will support the Project Scientist by evaluating ToO requests and generating the order should the Project Scientist declare a ToO.

2.5 LAT Instrument Science and Operations Center (LISOC)

The LAT Instrument Science and Operations Center (LISOC) is located at the Stanford Linear Accelerator Center (SLAC). The LISOC performs higher-level data processing (Level-1 &2) using the Level-0 data provided by the MOC and provides level-1/2 data to the GSSC. In addition, the LISOC archives and distributes science data products to the LAT collaborators.

The LAT ISOC will be responsible for all LAT instrument command and load activity planning, trending and performance analysis for LAT health and safety, and anomaly investigation as well as supporting the FOT in instrument calibration activities.

2.6   GBM Instrument Operations Center (GIOC)

The GBM Instrument Operations Center (GIOC) is located at the National Space Science and Technology Center (NSSTC) in Huntsville, AL and is a collaborative effort between Marshall Space Flight Center (MSFC), the University of Alabama in Huntsville (UAH) in the United States and the Max Planck Institute for Extraterrestrial Physics (MPE) in Garching, Germany.

The GIOC performs higher-level data processing (Level-1 &2) using the Level-0 data provided by the MOC and provides level-1/2 data to the GSSC. In addition, the GIOC archives and distributes science data products to the GBM collaborators.

The GBM IOC will be responsible for all GBM instrument command and load activity planning, trending and performance analysis for GBM health and safety, and anomaly investigation as well as supporting the FOT in instrument calibration activities.

The GIOC will provide the MOC with a Burst Alert Processor (BAP), which will reformat Burst Alert Telemetry from both the GBM and the LAT as GCN Notices and submit them to the GCN. The BAP will also autonomously calculate and submit to the GCN an improved burst position from the GBM data transmitted in the burst alert telemetry. Using GBM burst alert telemetry and the full GBM data analyzed under human supervision, the GIOC may calculate and submit to the GCN refined burst positions. The GIOC may also submit GCN circulars reporting other burst information such as spectra, duration, and fluence.

2.7   High Energy Astrophysics Science Archive Research Center (HEASARC)

The High Energy Astrophysics Science Archive Research Center (HEASARC), located at NASA/GSFC, is the permanent archive for GLAST data products, calibration data and documentation.   The GSSC provides the HEASARC with the Flexible Image Transport System (FITS) file data products as the permanent GLAST archives.

The HEASARC will archive GLAST data for the life of the mission and many years beyond in support of astronomical research by the science community. These archives will make the data available electronically to everyone, regardless of affiliation. The data will be automatically processed as soon as it is down linked and will be sent directly to the archives some time after the first year (during which the non-transient data are proprietary to the instrument teams). The LHEA, Code 660, at GSFC is implementing the modifications needed to accommodate the GLAST mission.

2.8   GRB Coordinates Network (GCN)

The GRB Coordinates Network (GCN) is an existing system that is operated by the Laboratory for High Energy Astrophysics at GSFC. It currently has sufficient capacity to support the GLAST mission. GSFC Code 660 is implementing the GLAST GCN Front-End.

The GCN distributes location and light curve information for GRBs detected by all spacecraft capable of detecting GRBs to interested members of the science community. The rapid dissemination of GLAST alerts and finder fields will enable ground observatories and operators of other spacecraft to plan correlative observations.

For GLAST, a GCN Front-End will receive the LAT Burst Alert Telemetry and the GBM Burst Alert Telemetry from the MOC BAP in the form of GCN Notices. The BAP will perform the necessary processing and filtering, and will pass appropriate messages on to the GCN.

2.9   Flight Dynamics Facility (FDF)

Although the primary means of orbit determination will be via the Global Positioning System (GPS), the Flight Dynamics Facility (FDF), located at NASA/GSFC, will be able to provide orbit determination based on Two-Line Elements (TLE) from the North American Air Defense Command (NORAD) and Differenced One-Way Doppler (DOWD) data from TDRSS. The FDF will provide the MOC with the orbit data via an existing institutional interface.

FDF support will be provided from the existing facility in Building 28 at GSFC. The FDF will not require any significant modifications to support the GLAST mission.

In addition to supplying backup orbit determination, the FDF may also be utilized to verify observatory attitude. Details on this support are still being negotiated.

2.10   Spacecraft I&T Facility (Spectrum Astro Incorporated)

The Spacecraft I&T facility is located in Gilbert, Arizona and is managed and controlled by Spectrum Astro Incorporated (SAI). During the pre-launch and testing phase, the I&T facility provides access to the spacecraft and instruments and operations simulation activities. Copies of the ITOS software will be hosted in the I&T facility for use by Spectrum Astro and the FOT. During nominal operations, there is an option in the contract to allow the spacecraft contractor to provide spacecraft FSW maintenance.

2.11   Launch Site

The GLAST observatory will be launched from the Kennedy Space Center (KSC) Eastern Range located in Cape Canaveral, FL aboard a Delta 2920H-10. Telemetry and Command data flows will be conducted between the MOC and KSC prior to launch.

2.12   Ground Communications Network

The GLAST ground communications network is a collection of open and closed networks that provide data transport among the elements of the Ground System. For example, the MOC will interface with the SN WSC via a NASA Integrated Services Network (NISN)-provided dedicated link to NASA/GSFC, which will provide access to the existing institutional IONET closed network. This also provides the MOC with access to the FDF. Other data communications among the GLAST ground system elements will be via leased lines and open Internet

connections. Goldbelt Orca/Omitron will coordinate the implementation to ensure the necessary connectivity and security have been provided to support the MOC operations.

3.0 MANAGEMENT AND DEVELOPMENT APPROACH

This section describes the overall approach to managing and developing the GLAST Ground System implementation effort. It addresses the team organization, the associated development responsibilities and approach, and the planned approach to handling requirements, technical coordination, information dissemination, interface definition, schedules, configuration management, security, and risk management.

3.1 Development Organization

The GLAST ground system implementation team is comprised of a combination of government, contractor and university personnel. Figure 3-1 below illustrates the organization structure.
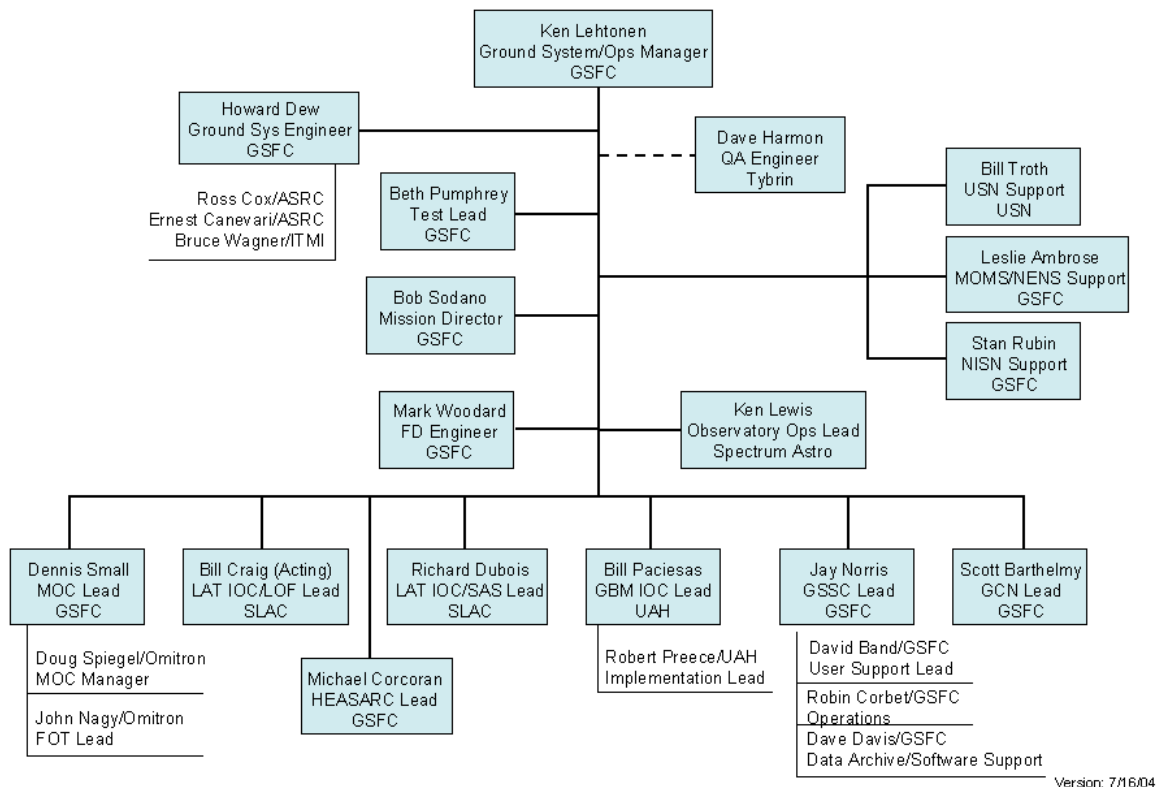
Figure 3-1: GLAST Ground System Team Organization

The sections that follow describe the roles and responsibilities of each of the members of the GLAST Ground System development team depicted in the above organization chart.

3.1.1 Ground System/Operations Manager (GSOM)

The Ground System/Operations Manager (GSOM), Ken Lehtonen/GSFC Code 581, has overall responsibility for ensuring that the Ground System requirements, interfaces and design, are

developed and documented, and that the Ground System is ready to support the GLAST launch by the launch freeze date. This ensures that the individual elements have been implemented and verified, and that the Ground System as a whole has been verified and meets all functional and performance requirements. The GSOM also manages and administers the Ground System and flight operations budget and schedule, leads the identification, management, and resolution of development and operations issues and risks, ensures operational readiness, and ensures that the configuration and discrepancy management processes are adhered to.

The GSOM will support the GLAST Project Manager, Kevin Grady/GSFC Code 492, who manages the overall GLAST Project. The GLAST Project Manager provides overall programmatic guidelines, requirements, and direction; establishes the overall schedule and budget; and, serves as a liaison between the Ground System and external organizations, such as the spacecraft contractor, as needed. Furthermore, the GSOM will negotiate the Ground System budget and schedule with the Project Manager.

The GSOM will work closely with the GLAST Systems Manager, Jack Leibee/GSFC Code 490 to ensure that the complete end-to-end system (observatory, ground system, and operations) is designed and implemented to function as one integrated system. The Systems Manager provides the primary technical interface with the Project and external organizations, particularly with the spacecraft and instruments. The Systems Manager leads the Project's risk and configuration management processes, which are supported and used by the Ground System.

3.1.2   Ground System Engineer

The Ground System Engineer, Howard Dew/GSFC Code 581, is responsible for assisting the GSOM in the technical management of the Ground System development effort. The Ground System Engineer will be supported by a team of systems and operations engineering contractors. The Ground System Engineer will be the main technical point of contact with the Project's Systems Management Team. The Ground System Engineer will act on behalf of the GSOM when needed.

The Ground System Engineer and his supporting engineering team are responsible for working issues related to requirements, internal and external interfaces, testing, voice and data communications, and IT security. The Ground System Engineering Team will also help to ensure that the Ground System requirements and design are adequately factored into the operations perspective (and vice versa). Contractors from ASRC Aerospace Corp and ITMI are currently supporting the Ground System engineering effort.

The Ground System Engineer is responsible for leading the implementation of the GLAST front-end system that will be needed at WSC to process and forward incoming GLAST Ku-band telemetry data.

The Ground System Engineer is responsible for chairing the GLAST Ground System Discrepancy Review Board (DRB) once ground system testing begins.

3.1.3   Ground System Test Lead

The Ground System Test Lead, Beth Pumphrey/GSFC Code 586, has the primary responsibility for administering the Ground System test program. The Test Lead is responsible for developing and maintaining the appropriate test program documentation (e.g., Ground System Verification Plan), and chairing the Ground Readiness Test Team (GRTT) meetings. The Test Lead will receive direct support from the Ground System Engineering Team.

3.1.4   Mission Director

The Mission Director, Bob Sodano/GSFC Code 581, will be the lead for long-term mission operations support after the observatory has been accepted on orbit (i.e., shortly after the 60-day L&EO phase). This will require coordination with the spacecraft contractor, instrument operations teams, science operations team, and the flight operations team to ensure that the mission is operating safely and efficiently, and meeting science objectives. While primarily an operations position, the Mission Director is a member of the development organization to help ensure that the Ground System requirements, design and implementation are appropriate for long-term operations. The Mission Director will also lead the efforts to design and implement the MOC facility at Goddard that will support GLAST mission operations.

3.1.5   Customer Commitment Manager

The GLAST Customer Commitment Manager, Leslie Ambrose/GSFC Code 451, is responsible for ensuring that the institutional services required by the GLAST mission are defined, documented, budgeted, and implemented. These services primarily include the Space Network, Ground Network, and Flight Dynamics Facility. The Customer Commitment Manager will ensure that these requirements are documented in the Project Service Level Agreement (PSLA) and that any other needed documents related to these institutional services specific to GLAST are generated.

These services will be provided via a combination of two contracts, namely the Mission Operations and Mission Services (MOMS) contract and the Near Earth Network Services (NENS) contract.

3.1.6   NISN Support Lead

The NASA Integrated Services Network (NISN) Support Lead, Stan Rubin/GSFC Code 291, is responsible for ensuring that the NISN services required by the GLAST mission are defined, documented, budgeted, and implemented. These are the NASA institutional data and voice communications services that will be needed for mission operations support.

3.1.7   Commercial Ground Station Support Lead

The Commercial Ground Station Lead, Bill Troth (USN), is responsible for ensuring that the South Point, Hawaii and Dongara, Australia Ground Stations are ready to support the pre-launch test activities and spacecraft launch as scheduled. The Commercial Ground Station Lead is also responsible for ensuring that the proper interface documentation is either generated or supported and that any needed test equipment is provided to NASA for test support.

3.1.8   MOC Implementation Lead

The MOC Implementation Lead, Dennis Small/GSFC Code 584, is responsible for the implementation of the Mission Operations Center at GSFC. The MOC Implementation Lead administers the contract with Goldbelt Orca/Omitron to implement the MOC and provide Flight Operations Team support. This includes ensuring that MOC-related requirements, interfaces and design are developed and documented, and that the MOC is ready to support the GLAST ground system readiness tests and operations simulations as scheduled.

The MOC Implementation Lead is responsible for ensuring that the instrument requirements, capabilities, and other operations considerations are factored into the MOC implementation effort and, likewise, that ground system considerations are made known to the instrument teams to help influence instrument design.

3.1.9   GLAST Science Support Center (GSSC) Management

3.1.9.1 GSSC Manager

The GSSC Manager, Jay Norris/GSFC Code 661, is responsible for the GSSC budget and staffing, the development of the GSSC prior to launch, the operations of the GSSC post launch, and the final archiving at the end of mission of the data products ingested or produced by the GSSC. The GSSC is organized into three sections, each with a section lead. The GSSC Manager reports to the GSOM on GSSC operations and to the Project Scientist on science issues.

3.1.9.2 GSSC User Support Lead

The GSSC User Support Lead, David Band/Code 661/UMBC, manages the Guest Investigator (GI) Program and development of User Support tools. The GSSC User Support Lead reports to the GSSC Manager.

3.1.9.3 GSSC Operations Lead

The GSSC Operations Lead, Robin Corbet/Code 662/USRA, manages the development of GSSC operations tools, and is the GSSC interface to the MOC. The GSSC Operations Lead reports to the GSSC Manager.

3.1.9.4 GSSC Data Archive and Software Support Lead

The GSSC Data Archive and Software Support (DA/SS) Lead, Dave Davis/Code 662/UMBC, manages the development and operation of the database, ingest, and archive systems, and the GSSC contribution to development of the LAT science analysis tools, the latter in concert with Seth Digel (LAT). The Software Lead, Robert Schaefer, reports to the DA/SS Lead; the Software Lead integrates programmer efforts across the three GSSC sections. The GSSC DA/SS Lead reports to the GSSC Manager.

3.1.10 LAT Instrument Operations Center (LISOC) Management

3.1.10.1   LISOC Subsystem Manager

The LAT ISOC Subsystem Manager, Bill Craig (Acting)/Stanford Linear Accelerator Center (SLAC)/ONE, is responsible for the LISOC budget and staffing. He is responsible for the development of the LISOC prior to launch, the operations of the LISOC post launch. The LISOC Manager reports to the GSOM on LISOC operations and to the Project Scientist on science issues.

3.1.10.2   LISOC Science Analysis Software (SAS) Manager

The LAT Science Analysis Software (SAS) Subsystem Manager, Richard Dubois/SLAC, is responsible for the development of LAT simulation and reconstruction software and engineering model and I&T support prior to launch; the development of the high level science analysis tools; pipeline development and processing of Level-1 data products; and the maintenance and support of LAT ground software. The LAT SAS Manager reports to the LAT IPO (Instrument Program Office)   Project Manager, but supports the GSOM for areas related to science operations, data processing, and ground system interfaces.

3.1.11 GBM Instrument Operations Center (GIOC) Management

3.1.11.1 GBM Instrument Operations Center (GIOC) Manager

The GBM IOC Manager, Bill Paciesas/UAH, is responsible for the development of the GIOC prior to launch, the operations of the GIOC post launch, the processing of Level-1 data products, delivery of the Burst Alert Processor (BAP) to the MOC and the maintenance of GBM flight software. The GIOC Manager reports to the GSOM on GIOC operations and to the Project Scientist on science issues.

3.1.11.2 GBM IOC Implementation Lead

The GBM IOC Implementation Lead, Robert Preece/UAH, is responsible for leading the development of the GBM IOC hardware and software.

3.1.12 Spacecraft Operations Development Lead

The Spacecraft Operations Development Lead, Ken Lewis/Spectrum Astro, is responsible for ensuring that the operations aspects of the spacecraft capabilities and design are factored into the Ground System design. While this Lead role is primarily operational in nature, it is an explicit part of the development organization to help ensure that spacecraft operations considerations are known and understood by the development team and factored into the Ground System design.

3.1.13 HEASARC Lead

The HEASARC Lead, Michael Corcoran/GSFC Code 662, is responsible for ensuring that the institutional modifications needed for supporting the GLAST mission are identified,

documented, and implemented. The Lead is also responsible for ensuring that the HEASARC is capable of receiving data from the GSSC and supporting the GLAST ground system readiness tests and operations simulations as scheduled.

3.1.14 Ground System Quality Assurance (QA) Engineer

The Ground System QA Engineer, Dave Harmon/Tybrin, is responsible for ensuring that the Ground System Team adheres to the processes described in the Ground System Mission Assurance Requirements document and its associated deliverables. The Ground System QA Engineer will also independently monitor the ground system's risk management process as documented in section 3.9 of this document and will act as the Ground System Risk Manager (GSRM). He will assure that all risks that meet the established criteria are brought to the Ground System Project level either by him or the GSOM.

The GSRM will be responsible for administering the ground system risk management system for the GSOM and will ensure that the current set of risks in the Ground System's Risk Information Database (RID) is kept up-to-date on the Ground System Web site. He will also work directly with the ground system team in identifying and assessing ground system risks.

3.2   Development Approach

The organizations involved in designing and implementing each of the Ground System elements are described in Section 2, which provides an overview of the Ground System. This section summarizes the approach to be used to develop the Ground System.

3.2.1   Development Methodology

The functional Ground System software will be developed using the waterfall life cycle model, where elements will deliver capabilities incrementally in a series of builds or releases. The allocation of capabilities to builds will be documented by each element in element level development or release plans. There will, however, be a level of coordination at the Ground System level so that in a given timeframe the collection of builds across the elements complement each other. This will primarily be driven by the Ground System Test Plan, which will call out specific ground system capabilities that are needed for the Ground Readiness Tests in specific timeframes. This will serve as a guide to assist each element in planning and scheduling build deliveries and build contents.

Each element will conduct internal requirements generation, design, and code walkthroughs as part of the development methodology as well as system level peer reviews discussed later in this section. Prior to integration, unit testing will be conducted to ensure that each individual software component functions as designed/planned; where appropriate, string and/or system testing of related units will also be conducted. After software integration, the system will be acceptance tested, which will be the first time that all components in a build have been tested together as an integrated system. Upon completion of successful acceptance, the build will be demonstrated to the GSOM. Along with the demonstration, each build delivery will include a description of the build capabilities, a summary of the testing performed on the build, and a list of any problems that still exist with the build.

3.2.2 Ground System Reviews

The Ground System will provide opportunities for external reviews during the development phase through a series of formal reviews in accordance with the MAR (433-MAR-0004). These include the Ground System Requirements Review (GSRR), a series of Peer Reviews, and the Ground System Design Review (GSDR). The Ground System reviews will involve a presentation by the development team to a formal review board, chaired by the GSFC System Review Office (Code 300) with representation from the GLAST Headquarters Independent Review Team (IRT). Board members will be chosen by the Code 300 chair, but generally will consist of Goddard personnel with experience in ground system development and mission operations. The reviews shall be held to provide a greater understanding and an in-depth look at the GLAST Ground System and the processes used to design, implement, test, verify and validate. Problems or concerns identified during the reviews will be documented via Request for Action (RFA) forms. The GSOM is responsible for ensuring that all ground system related RFAs are responded to in a timely manner.

3.2.2.1 Ground System Requirement Review (GSRR)

The Ground System Requirements Review (GSRR) was held July 2003 at GSFC. It provided the plan and schedule for managing, implementing and testing the GLAST ground system. The GSRR provided the review board with the technical information necessary to evaluate the driving requirements for the Ground System and the operational context from which these requirements were derived. The Ground System Engineering Team presented the test approach, the tools available for verification and the mechanism by which requirements verification will be tracked. The GSRR introduced the framework of the Operational Readiness plan, which demonstrated how operations would mature in concert with system implementation. In addition, the documentation plan and schedule was presented. The risk mitigation plan and the strategy for assessing risk were also addressed.

3.2.2.2 Element Level Design Peer Reviews (DPR)

A series of Element Level Design Peer Reviews (DPR) will be held for the MOC (including the GLAST Front End Processor (GFEP) and FDF support), the IOCs (LISOC and GIOC), and the GSSC. At the first Design Peer Review, the elements shall present the level-4 requirements, and preliminary design and interface definitions. Each element shall document the requirements in an equivalent System Requirements Document and the design in a Design Specification.

A Detailed Design Peer Review (DDPR) will be held approximately six months after the first Design Peer Review and will address the concerns raised by the review panel at the DPR and provide additional detailed insight into the matured element design. The exception is the LAT ISOC, which will have a Critical Design Review (CDR) in lieu of a Detailed Design Peer Review.

The Design Peer Review and the Delta Design Peer Review will contain the same basic contents and vary only in the level of detail provided. The elements shall at a minimum present:
- o organization/work breakdown structure
- o configuration and risk management and product assurance approaches
- o the Level 4 requirements,

- o the mapping of requirements to the element subsystems/components,
- o the definitions of element external interfaces,
- o the approach to and schedule for element development and testing,
- o the element system (hardware and software) design, and
- o open risks and issues, and mitigation strategy.

At the Peer Reviews, the requirements, requirements mapping, and development plan/schedule shall be mature and complete. The other Peer Review items can be at an intermediate stage of maturity.

The elements shall accept and respond to Request For Actions (RFAs) generated at the Peer Reviews. Participants in the Peer Reviews (the Peer Review Panel) shall be jointly selected by the contractors and GSFC. Representatives from the Code 300 Ground System Review Team will be invited to participate in the Peer Reviews.

3.2.2.3 Ground System Design Review (GSDR)

After the element level DPRs, the overall Ground System design will be presented to the GSFC System Review Office Review Team at the GSDR. The primary objective is to demonstrate that the requirements, interfaces, and design are of sufficient maturity to begin ground system development. The Ground System shall at a minimum present the items mentioned in the above Peer Review section, with all items being at a complete and mature state.

3.2.3   Project Level Reviews

The Ground System will also provide the needed support for the higher-level Project Reviews and operations-oriented reviews. These include the following:

- o Mission Preliminary Design Review (MPDR) – held June 2003
- o Mission Critical Design Review (MCDR)—mid-September 2004
- o Mission Operations Review (MOR)
- o Operations Readiness Review (ORR)

The MPDR and MCDR are mission level reviews that address the design of the end-to-end system (i.e., spacecraft, instruments, and ground system). The MOR and ORR are operations reviews and are lead by the GSOM and are described in more detail below.

3.2.3.1 Mission Operations Review (MOR)

The MOR will describe the schedule and approach for achieving operational readiness. The primary focus will be on the development and validation of products (primarily command PROCs and Databases) and the plan for conducting operations simulations and rehearsals. As per all reviews, open risks and issues and strategies for mitigation will be addressed.

3.2.3.2 Operations Readiness Review (ORR)

The primary objective of the ORR is to present the launch readiness of the Ground System, and

operations products, processes and personnel. It will provide closure of actions from the MOR. All new requirements and changes in the Operations Plan will also be presented. At the ORR, the Ground System will provide test result summaries in the form of the *Requirements Verification Matrix* and the Project's assessment of the criticality of open problems. A schedule of work remaining for launch preparedness will be presented that describes the remaining tests, simulations and open problems. The status of all contingency procedures and the development and final system verification and validation status will also be provided. The ORR will provide details as to the location of all Project office, operations, and spacecraft subsystem expert personnel during the L&EO and In-Orbit Checkout (IOC) phases.

3.2.4   Development Metrics

Development metrics for each individual build for each element will be managed primarily at the element level. The implementation lead for each element is responsible for analyzing the development metrics and reporting any problems to the GSOM. While primarily managed at the element level, the GSOM will however have insight into the progress being made on module development, module/unit testing, module integration, etc., and will work closely with the element lead if needed to resolve any scheduling problems.

The primary metric for measuring the progress of overall ground system development is the test matrix. The Requirements Verification Matrix will contain a list of all ground system test requirements, a date for when they will be tested, and a status indicator. As the test program is administered, the progress of ground system development will be able to be quantitatively measured in terms of planned vs. actual requirements verified over time. The GSOM will be able to see which areas are having problems and what level of criticality they have to being ready for launch (i.e., launch critical requirements). The two key factors that make this method effective are (1) to have incremental deliveries so that progress can be adequately measured over time and (2) to schedule completion of Ground System testing well before launch, leaving time for fixes and any late requirements implementation.

Another metric to be used by the GSOM for measuring and analyzing development progress is the GLAST Ground System schedule, discussed later in this section. Each month the status of each element and any other ground system activities or product development will be factored into the schedule. This will be regularly compared to the baseline. Since the schedule will have key dependencies identified, it will help the development team recognize when a schedule change, such as a build delivery slip, will impact other areas of the schedule, such as a specific ground system test that uses that build.

3.2.5   *Development Facilities*

The only GLAST-unique development facility will be for the MOC. Other Ground System elements are institutional systems and will use their existing institutional development facilities. For the MOC, development will be supported at the MOC contractor (Goldbelt Orca/Omitron) facility. Portions of the MOC system will be temporarily installed at the I&T facility to facilitate testing efficiency, during some of the early Ground System testing. This hardware will then be moved to the GSFC MOC.

3.2.6 Hardware Acquisition Plan

The hardware needed for the Ground System is readily available from commercial vendors.

3.3 Ground System Requirements

The GLAST Ground System requirements will be formally documented in the *GLAST Ground System Requirements Document (GSRD)*. These requirements will be derived from and be consistent with the *GLAST Mission System Specification*, which in turn is derived from the *GLAST Science Requirements Document.* The GLAST Interface Control Documents will also be a source for GLAST Ground System requirements. In addition to the GLAST Ground System requirements, the set of requirements being levied on NASA institutional services, such as SN, FDF and Voice/Data communications, will be documented in a Project Service Level Agreement (PSLA). The Element level Functional and Performance Requirements (F&PR) Specifications will trace ground system requirements to the GSRD.

The individual elements will generate element-level requirements documents that will decompose the relevant portions of the GLAST Ground System-level requirements into the lower level detail needed for software design and development. These will be traced appropriately to the GSRD. The hierarchy for the overall GLAST requirements documents is depicted in Figure 3-2 below.
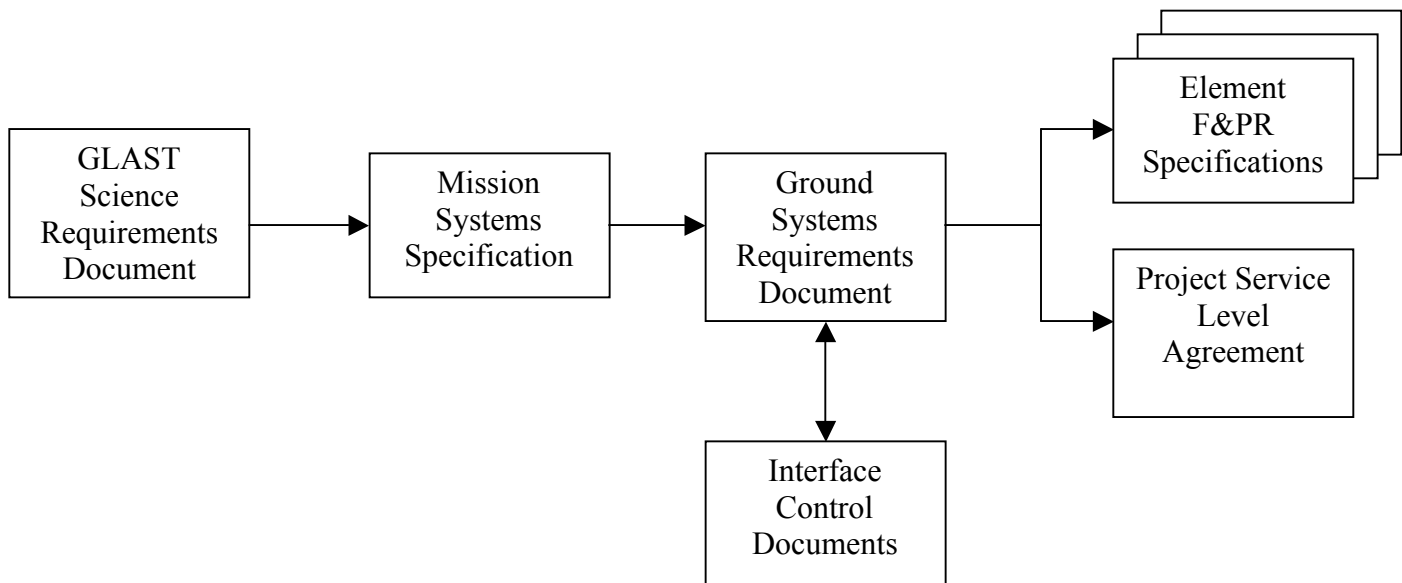

Figure 3-2: GLAST Ground System Requirements Hierarchy

The GLAST Ground System requirements document will be baselined with the GLAST Project Configuration Control Board (CCB), chaired by the GLAST Project Manager.

3.3.1   ITOS Requirements

Given that the ITOS software is the core telemetry and command system for the MOC, it is critical that the specific items needed by the GLAST mission be identified and documented. Consequently, the MOC Lead will develop and maintain a GLAST ITOS requirements document, titled *GLAST-Unique Requirements for ITOS*, that specifies the requirements levied on the generic ITOS software system that are driven by or unique to the GLAST mission. This document will identify the GLAST-unique ITOS requirements, the requirement drivers (e.g., MOC or spacecraft I&T), and the need date. The document will be baselined with the GLAST Ground System and Operations CCB.

3.3.2   Requirements Verification Matrix

The *Ground System Requirements Verification Matrix* is a low level document that will be used to document the complete set of Level-3 ground system requirements that will be explicitly tested as part of the Ground System testing process (described in Section 4 – Testing Approach). It will include all requirements from the *GLAST Ground System Requirements Document*.

The *Ground System Requirements Verification Matrix* will be used to record, track, and manage the validation and verification state of ground system requirements that drive the test process. This is discussed again in Section 4. The matrix will be generated and maintained by the Ground System Test Lead and will be baselined with the Ground System and Operations CCB. Updates will be maintained on the GLAST Ground System Web site so that the entire Ground System team has ready access to the information. The Ground System Test Lead will ensure that the Requirements Verification Matrix is updated appropriately whenever changes are made to the parent documents listed above.

Note: Element level-4 requirements will be tested by the individual ground system elements.

3.3.3   Requirements Criticality

In developing and testing the Ground System, it is vital that the team have a common understanding of which capabilities are critical to supporting launch and early orbit activation activities and which are needed for normal mission operations support. This will be addressed in two ways.

First, the Ground System functions that are critical for launch will be documented in the Ground System Requirements Document (*GSRD)*. These are the functions that must be available in order for the Ground System to declare launch readiness. Examples include the ability to receive and decommutate telemetry data and to construct and transmit command data.
Secondly, the individual requirements in the *Ground System Requirements Verification Matrix* will be assigned a launch critical indication, based on the functionality to which it is associated. This will help guide the Ground System test planning and conduct, and it will provide the needed guidelines for prioritizing work, particularly when managing the repair of Ground System discrepancies as the launch date is approached, which is discussed further in Section 4 – Testing Approach (Discrepancy Management).

3.4   Interfaces

The elements within the GLAST Ground System have requirements addressing a variety of internal and external interfaces. Each of these interfaces will be defined and documented in a formal Interface Control Document (ICD). For the GLAST Ground System internal interfaces, such as between the MOC and GSSC, the GLAST Ground System and Operations CCB will manage the related ICD. For interfaces that involve systems outside of the GLAST Ground System, the GLAST Project CCB will manage the relevant ICDs. The latter is needed because aspects of the ICD or any related issues might affect organizations outside the control of the GSOM. This also ensures that any interfaces that affect components outside of the Ground System receive Project-level review and consideration. The following ICDs will be used in the definition of the Ground System interfaces:

ICD	Lead
Spacecraft/Ground	SAI (CDRL 4)
Spacecraft/SN	Code 450 with SAI input (CDRL 23)
Operations Data Products ICD (MOC-GSSC/IOC)	FOT
Science Data Products ICD (GSSC/IOCs)	GSSC
MOC/FDF	Code 590/MOMS
MOC/Ground Station	FOT
DAS/Customers (453-ICD-DAS/Customer)	NASA - institutional
NCC Data System/MOC (451-ICD-NCCDS/MOC)	NASA - institutional
Database Data Format Control Document	Ground System Engineer

3.4.1 Project Data Base (PDB)

The Project Data Base (PDB), which is jointly managed by the GSOM and the GLAST Systems Manager, is used across multiple elements of the GLAST Ground System and therefore is treated as a system interface. The format of the database that will be interchanged between the elements will be documented in the *Database Data Format Control Document (DFCD)*, which is based upon the ITOS version 7.2 database format. The PDB consists of inputs from the Observatory Telemetry and Command (T&C) Database provided by SAI and the FOT-provided inputs for the ground system (e.g., station status messages). The PDB is created and managed by the FOT.

SAI will be responsible for ingesting the LAT and GBM instrument I&T databases and FSW inputs, and merging them with the spacecraft definitions to create the Observatory T&C Database prior to launch (post launch changes to the PDB are discussed in the GLAST MOA). This Observatory T&C Database will be validated by SAI and delivered to the MOC.

The GSOM will ensure that the proper version of the PDB is delivered and that the delivery schedule to the entire GLAST Ground System (e.g., ITOS, IOCs, GSSC, and PSS) is maintained and that verification is performed on the entire PDB prior to launch. The Project Database will be under the control of the Ground System and Operations CCB.
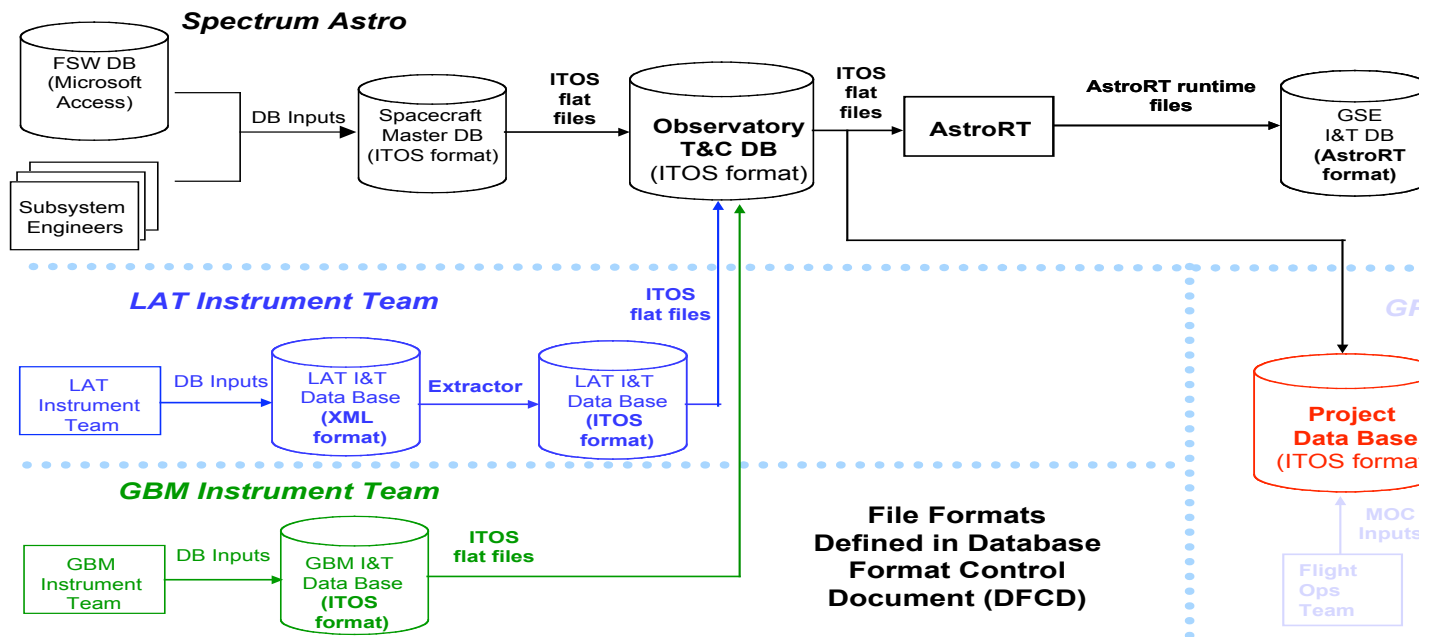
Figure 3-3 – Project Data Base Flow

3.5 Technical Coordination and Information Dissemination

Successful development of the GLAST Ground System ground system requires efficient approaches to coordinating communications and disseminating information among team members. The GLAST GSOM will utilize several tools to accomplish this:

- *GLAST Ground Operations Working Group (GOWG) Meetings*– The GOWG is a weekly staff meeting that will be held to give team members the opportunity to present status, to identify, discuss and assess risks and issues, and to initiate and close out any action items. It will facilitate face-to-face communication among team members and help ensure that the GSOM is kept appraised of implementation progress, issues, etc. The meetings will also provide an efficient vehicle to discuss topics and issues that affect all ground system elements such as the Project Database. They will be chaired by the GSOM. Team members who cannot physically attend the meeting will have the opportunity to participate remotely via teleconference.

The GOWGs will also be used to facilitate discussion among instrument team and Ground System personnel. It will help to ensure that Ground System personnel understand the design and capabilities of each of the two instruments and, likewise, for the instrument teams' understanding of the Ground System. Participation will primarily be via teleconference since related personnel are located around the country and Europe. Minutes for each meeting will be generated by the operations contractor and made available to the team via the GLAST Ground System Web site. These minutes will also track any action items assigned during the meetings.

- *Technical Interchange Meetings (TIMs)* – TIMs will be held as needed to work lower level technical topics and issues. Highlights of these meetings will be documented as appropriate and addressed at the GLAST Operations Working Group meetings.

- *GLAST Ground System Web Site* – A GLAST Ground System home page Web site will be maintained so that all ground system-related documentation can be easily made available to the team. It is located at URL http://glast.gsfc.nasa.gov/project/gsmo. Items to be placed on the site will include GLAST GOWG meeting minutes, documents, review packages, and technical memorandums. The site will be password protected so that only authorized GLAST team members can access the information. It will be managed and administered by the GSOM. This site will be linked with the higher level GLAST Project Web site, which contains Project-level items such as documents that are managed by the Project CCB and packages from Project reviews. The GLAST Project Web site is located at URL http://glast.gsfc.nasa.gov/project/.

- *Ground System Discrepancy Review Board* (DRB)– All Ground System related anomalies and requested enhancements will be identified, monitored, tracked, and closed through the GLAST DRB. The DRB will accept/reject or forward DRs to the appropriate CCB. Accepted Discrepancy Reports (DRs) will be dispositioned based on their potential impact to operations and assigned a severity and priority by the Board. The GLAST Ground System Engineer will chair the Board.

- *Ground Readiness Test Team Meetings – GRTT Meetings –* The GRTT meeting will be used to determine test objectives, schedules, and status test readiness. The Ground System Test Lead will chair the meeting.

3.6   Schedules

A GLAST Ground System development schedule will be maintained that identifies dates for all key ground system activities or deliverables. These include element deliveries (software, documents, etc.), ground system tests (and associated documentation), and operations simulations (and associated documentation). The schedule will identify major dependencies, both within and outside the GLAST Ground System. It will be regularly reviewed with the team by the GSOM, and the latest schedule will be maintained by the GLAST Ground System Engineer and placed on the GLAST Ground System Web Site.

The Ground System schedule will actually be a subset of the formal GLAST Project-level schedule, so that key milestones and dependencies can be more easily tracked and analyzed. The schedule will be developed and maintained by schedule resource personnel provided by the GLAST Project and will be implemented using Microsoft Project software.

3.7   Configuration Management

There will be three levels of configuration management used by the Ground System: at the GLAST Project level, at the Ground System and Operations level, and at the Element Level. Items managed at the GLAST Project level will be managed and controlled by the GLAST Project Configuration Control Board (CCB), which will be chaired by the GLAST Project

Manager. The GSOM will represent the Ground System on this board. GLAST Project level items are those that involve systems or organizations outside of the scope of the Ground System. Examples include Project level requirements documents (which contain ground system and non-ground system requirements) and ICDs between the Ground System and the spacecraft.

The GLAST Ground System and Operations CCB will manage controlled items that only involve elements or organizations within the scope of the Ground System and mission operations. Examples include ground system element requirements documents, ICDs between ground system elements, and operational products (e.g., databases and PROCs). The GLAST Ground System and Operations CCB will be chaired by the GSOM and will be comprised of representatives from each ground system element and from the Project Systems Management Office. Details for managing ops products will be in the *Mission Operations Readiness Plan*.

Both CCBs will use the Web-based Configuration Management System (CMS). The CMS provides the ability to baseline-configured items, such as documents, and request changes to configured items via electronic Configuration Change Requests (CCRs). Organizations are provided the opportunity to respond to each CCR from both the technical, schedule, and cost perspectives.

Configured items for the Ground System generally include any item where it is important to have team consensus on the item and where changes to that item could impact cost, schedule, or risk. The following table addresses documents relevant to the Ground System development and under which CCB they are controlled:

Table 3-1: Ground System Document CCB level

Document	CCB Level
Ground System Implementation Plan	Project
Ground System Requirements Document (GSRD)	Project
Spacecraft/Ground	Project
Spacecraft/SN	Project
Operations Data Products ICD	Ground System
Science Data Products ICD	Ground System
MOC/FDF	Ground System
MOC/Ground Station	Ground System
Ground System Test Plan	Ground System
IT Security Plan, IT Risk Management Plan, and Contingency Plan	Ground System
Operations Concept Document (OCD)	Project
Project Service Level Agreement (PSLA)	Ground System
Element Level Requirements*	Ground System
Database Data Format Control Document (DFCD)	Project

Other Element Level documents, such as the element development and test plans, will be under internal configuration management by the elements and covered by the element CM plans.

* With the exception of the GSSC Functional Requirements Document which is under Project Control.

3.8   Security

There are two aspects of security for the Ground System: physical security of ground system facilities and system/network security. Physical access to mission critical GLAST ground system facilities will be protected by physical and/or key-card locks. System and network security will ensure that only authorized personnel are able to access the computer systems, employing appropriate levels of password protection or other means of authentication. Different levels of authorization will be enforced depending on the function being performed. An example of two functions with much different authorization levels is access to science data for analysis and access to the ability to send commands to the spacecraft.

An *IT Security Plan, IT Risk Management Plan,* and *Contingency Plan* will be developed by the Ground System Engineer that will address the approach being used to ensure that adequate security is designed into the Ground System. The GLAST Ground System is required to be NPG 2810.1 compliant.

3.9   Risk Management

Risk management is defined as an organized, systematic decision-making process that efficiently reduces or eliminates risks to achieving program goals. A program risk is any circumstance or situation that poses a threat to: personnel or observatory safety, Program controlled cost, Program controlled schedule, or major mission objectives, and for which an acceptable resolution is deemed unlikely without a focused management effort.

The Ground System will utilize a risk management process based upon the process used by the GLAST Project. Like the GLAST Project, the GLAST Ground System will identify, analyze, plan, track, and control risks. The following sections describe each of these tasks in detail:

3.9.1 Risk Identification

The objective of risk identification is to locate risks before they become problems. To identify a risk, Ground System Team members will create a risk statement and forward it to the Ground System Risk Manager (GSRM). The risk statement will contain the risk condition, consequence, context statement and recommended priority. The GSRM will present the risk at the next scheduled GOWG that conducts risk management. If the priority of the risk is high, then the GSRM will ensure the risk is presented at the next GOWG.

3.9.2 Risk Analysis

The objective of risk analysis is to convert risk data into decision-making information. Once a GLAST Ground System technical or programmatic risk has been identified and written as a risk statement in the Risk Information Database (RID), it is then analyzed.

These identifiers for risk weighting at the system level are:

- Impact   the severity if risk should materialize
- Probability   the likelihood of risk occurrence

LEGEND

■ High – Implement new process(es) or change baseline plan(s)

■ Med – Aggressively manage; consider alternative process

■ Low - Monitor

What is the probability of the situation or circumstances happening?		
Level	Probability	The current process
5	Very High	Near Certainty
4	High	Highly Likely
3	Moderate	May prevent this event, but additional actions will be required
2	Low	Is usually sufficient to prevent this type of event
1	Very Low	Is likely sufficient to prevent this event

Impact / Probability matrix:

Impact					
5	11	16	20	23	25
4	7	12	17	21	24
3	4	8	13	18	22
2	2	5	9	14	19
1	1	3	6	10	15
	1	2	3	4	5

Probability

Given the event occurs, what is the magnitude of the impact to the mission?					
Level	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
Technical	Minimal or no Impact	Moderate reduction, same approach retained	Moderate reduction, workarounds required	Major Reduction, workarounds required	Must be Mitigated
Schedule	Minimal Impact	Additional activities required in order to meet need date	Level 2 Milestone slip of up to < = 1 month	Level 2 Milestone slip of > 1 month, or critical path impacted	Cannot achieve major program milestone
Cost	Minimal Impact of <$25k	Budget increase between $25k and $100k	Budget increase between $100k and $250k	Budget increase between $250k and $1M	Budget increase greater than $1M

Figure 3-4 – GLAST Ground System Risk Summary Scorecard

At the GOWG, the risk impact, probability, and time frame (i.e., time to start action or mitigation) will be determined for the individual risks. These values are maintained via the RID on the Ground System website by the Ground System Risk Manager. Figure 3-4 above represents how impact and probability are used to determine Ground System risk level (Numeric Value) and risk factor (Very Low to Very High). The technical, schedule and cost impacts will be equally weighted to determine the overall magnitude of the impact to the Ground System.

If the risk is accepted, the Risk Information Database is updated by the Ground System Risk Manager to reflect the new status. Upon acceptance, a risk mitigation lead will be assigned to the risk. That person will be held accountable for developing a **risk mitigation plan**, implementation of said plan; reporting status of the mitigation process; and proper closure of the risk.

3.9.3 Risk Planning

The objective of risk planning is to develop effective plans that over time produce the correct set of actions that minimizes risk and impacts. In this phase, the Ground System Project Team decides what action, if any, will be taken to manage/mitigate the risk or set of related risks. There are four **risk actions** that can be assigned to a risk. The options are:

- **Research** the risk to gain more information about it
- **Accept** the risk as stated and do nothing about it other than accept it
- **Watch** for identified "triggers" before taking any action about the risk
- **Mitigate** the risk to reduce or eliminate it

Characterization of a High Risk as "*Acceptable*" must be supported on the grounds that "all reasonable mitigation options (with-in cost, schedule, and technical constraints) have been exhausted and have the concurrence of the GSOM.

3.9.4 Risk Tracking

The objective of the Track function is to collect accurate, timely, and relevant risk information and to present it in a clear and easily understood manner appropriate to the person/group who receives the status report. The status reports generated during tracking are used by the Ground System Team members to make decisions about managing risks. In the risk-tracking phase the Ground System Team acquires, compiles, and reports information on selected risks. This information will be provided by the Ground System Risk Manager at GOWG meetings and be included on the agenda as required. Typically, the risks will be reviewed on a monthly basis. Risks can be reviewed more frequently if necessary.

3.9.5 Risk Control

The objective of the Control function is to make informed, timely, and effective decisions regarding risks and their mitigation plans. Controlling risks will be integrated and coordinated in the Ground System Team's routine management activities. The following are mitigation plan decisions:

- Re-plan (reassess the risk action as per section 3.9.3)
- Continue tracking and executing the current plan
- Invoke the risk mitigation plan
- Close the risk
- Elevate to Project Level Risk Management (see section 3.9.6)

Risks may be closed at the Ground System Level upon the successful completion of the risk mitigation plan, if the risk is reassessed and determined to be acceptable or if elevated to the Project Level.

3.9.6 Risk Elevation

Risks will be raised to the Project Level based on the trigger mechanism documented in Figure 3-4, which is consistent in design with that used by the Project for Project-level risks. Risks that have a Ground System high risk factor (i.e., a level of 18 or greater) will be raised to the Project Level. The scorecard has been calibrated so that the Ground System risks elevated to the Project Level will have a Project Risk Factor of no higher than medium at the time they are boarded with the Project.

Once a Ground System risk has been elevated and accepted at the Project Risk Management Level, the Ground System risk will be closed and tracked solely at the Project level. It will be at the discretion of the Project Risk Management group whether a risk shall be relegated back to the Ground System Risk Management Process or not once its risk factor has been sufficiently reduced.

4.0   TESTING APPROACH

GLAST Ground System readiness testing will be completed during the Project's Pre-Launch Operations phase. A *Ground System Test Plan* will be written that describes the series of tests that will demonstrate the Ground System's operational readiness to support the GLAST mission. Additionally, it will identify the configuration, target dates, and team members responsible for implementation, as appropriate. This document will be generated and maintained by the Ground System Test Lead.

The scope of the Ground System testing is limited to verifying the functionality and performance of the Ground System as defined in the Ground System requirements and to verify all interfaces. For external interfaces, such as with the spacecraft, the Ground System testing is limited to verifying that the Ground System has properly implemented the interface as specified in the appropriate ICD. It is not being conducted to verify functionality or performance of the external system itself, though if any problems are detected an appropriate anomaly report will be generated. The ground system testing will not verify the readiness of the operations personnel or products (e.g., command PROCs or T&C data base) to support the mission. Operations readiness will be specified in the *Mission Operations Readiness Plan* and will be verified via a series of operations simulations. The ground system implementation team's responsibility is to ensure that the system is able to support these operations readiness activities, and the Ground System test program described in this section will officially verify that this is the case.

The GRTT has at its disposal several simulator tools that will be used in the execution of the *Ground System Test Plan*. Table 4.1 provides an overview of the simulators that will be used by the GRTT to validate the GLAST Ground System.

Table 4-1 GLAST Simulators used for Ground System Verification.

Simulator	Provider	Use	Schedule
Portable Spacecraft Simulator (PSS)	GSFC Code 583	Initial MOC Testing; Ground System Testing	November 2004
Mission Training Simulator (MTS)	Spectrum and Instrument Teams	FOT Training, Ops Simulations, Ops Product Development/Test	September 2005
Spacecraft HotBench	Spectrum	For activities requiring spacecraft high-fidelity simulator support (e.g., selected contingency simulations)	Post-launch (but available starting at S/C I&T)
Software Development and Maintenance Simulator (SDMS)	Spectrum	Flight software maintenance	September 2005

As an absolute minimum, the MOC system must be located at the operational GSFC MOC facility in a launch support configuration for the End-to-End Test. This will ensure that any problems that may result from the different network connections are detected prior to launch. Similarly, a position has been established that all of the formal operations simulations must be conducted from the actual GSFC MOC facility as well.

4.1 Test Planning and Management

A Ground Readiness Test Team (GRTT) will be formed that will be responsible for developing the detailed plans and scripts for the Ground System tests and for analyzing results of each of the tests. The GRTT will be chaired by the Ground System Test Lead and will include representatives from the entire ground system development team for each element.

For each of the tests, a Test Script will be generated that provides more detail than is documented in the Test Plan. For example, while the Test Plan defines the objectives for a given test, the Test Script would provide the specific step-by-step details for how the test will be conducted and would identify the products and resources needed to conduct the test.

Prior to each test an appropriate Briefing Message will be distributed to ensure that all test participants have the information needed to conduct the test. This is particularly important when institutional resources are needed, such as SN support. After each test the GRTT will meet to discuss the results of the test, and a Debrief Message will be prepared and distributed to document the results.

4.2 Test Verification

As mentioned in Section 3, the Ground System Test Lead will generate and maintain a *Ground System Requirements Verification Matrix* (GSRVM). While the Test Plan documents the overall plan for ground system testing, identifies dependencies, and establishes the actual tests (listed in Section 4.3 below), the GSRVM will be the primary vehicle to record specifically what will be tested (i.e., the test requirements), when it will be tested, and the status of each of the test requirements at any given time for the GRT Tests. The GRTT will play an integral part in reviewing the requirements matrix and keeping it up to date with actual test status and progress. Up-to-date versions of the GSRVM will be maintained on the GLAST Ground System Web site to ensure that the team has ready access to the information and the information being accessed is current.

Additionally, the GLAST Project System Manager will generate and maintain a complete system-level Test Verification Data Base. This database will be used by the Project to track progress and status across all of the mission components, primarily the spacecraft, instruments, and ground system. For the Ground System, this database will contain requirements from the GLAST Ground System Requirements Document, which is the primary requirements document for the Ground System. The ground system entries in this Project-level database will be updated based on actual progress and status achieved in the Ground System testing process described herein. This will be accomplished by ensuring an adequate level of requirements traceability linkage between the Projects' Test Verification Data Base and the Ground System's Requirements Verification Matrix.

4.3   Acceptance Criteria

The GLAST Ground System development will be completed upon customer acceptance, which nominally occurs at the Operational Readiness Review (ORR). A complete end-to-end demonstration of the systems capabilities will be provided through the series of tests that will be performed as part of the operational readiness testing. The acceptance criteria will include specific tests to be executed, requirements to be satisfied by each test that will be specified in the Ground System Verification Plan with the results to be provided to the project. Acceptance of the system will be documented in the minutes of the ORR.

4.4   Test Summary

The GLAST ground system testing program will consist of a collection of tests that verify individual ground system element functionality and performance, internal and external interfaces, system operability, and end-to-end data flows. The following sections summarize the Ground System tests planned for the GLAST mission that will be documented in the *Ground System Test Plan*. The Flight Team product validation plan will be in the covered in the *Mission Operations Agreement (MOA)* and the *Mission Operations Readiness Plan*.

4.4.1   Element Acceptance Testing

The purpose of Element Acceptance Testing is to verify and validate functionality and performance of the individual elements that comprise the Ground System and to demonstrate element-to-element interface compatibility.

A structured, incremental approach is used for ground system testing, verification, and readiness. This includes a modular build strategy for ground system development, where each build or module is integrated and tested. Build or module testability is determined during design and code walkthroughs. Module testing confirms satisfaction of design requirements. A system acceptance test plan will be developed by each element that documents the approach to testing each of the planned deliveries. The main drivers for the element-level testing are the element-level requirements documents and the ICDs. The element-level testing for each build will ensure that it is ready to support the more formal ground system tests that will follow after delivery.

4.4.2   RF Compatibility Testing

RF Compatibility testing validates the ability of the spacecraft and ground system RF systems to communicate. It is comprised of a number of tests that verify all aspects of the RF interfaces and forward and return links. These tests will assess the spacecraft RF interface compatibility with the ground station and TDRS, measure the telemetry values at the ground station's receivers, and verify the spacecraft command receiver operations and the ability of the spacecraft to perform ranging.

All RF compatibility testing will be conducted while the spacecraft is in the spacecraft contractor facility (Gilbert, AZ). The Simulations Operations Center (SOC) at GSFC and the Compatibility Test Van (CTV) will be used to communicate with TDRS and the Space Network's (SN) Demand Access Service (DAS) at the White Sands Complex (WSC) and to forward data to the

MOC. RF compatibility between the spacecraft and the USN ground stations will also be performed. USN will provide an RF suitcase that will simulate the Commercial Ground Stations. The RF Suitcase will receive data from the RF transponder on the spacecraft and process it in accordance with the signed ICD. Then, the data will be transmitted to the MOC via the TCP/IP port on the back end of the RF Suitcase. Prior to testing with the spacecraft, verification of the RF Suitcase will be conducted using the Hot Bench and/or Portable Spacecraft Simulator.

4.4.3 Ground Readiness Testing (GRTs)

The purpose of the Ground Readiness Tests (GRTs) is to verify the Ground System interfaces, data flows, performance, and major functionality of the GLAST Ground System. This will be accomplished through a series of at least seven ground-system oriented tests using the simulators or recorded data. The objective is to have all functionality tested by the first 6 tests and to use the subsequent test for regression testing. GRTs will serve as the prerequisite to the End-to-End Tests where appropriate.

4.4.4 End-To-End (ETE) Testing

The GLAST project will perform a series of at least five end-to-end tests (approximately 2 days in length each) primarily between the MOC and the observatory. The objective of the initial tests will be to verify the compatibility of the MOC workstations at the spacecraft facility and at GSFC and the GLAST Observatory. As the systems mature, the end-to-end test will become more operational in nature and include additional ground system elements. These tests will verify data exchanges including telemetry, memory dumps, Solid State Recorder (SSR) operations, commands, command loads, and memory loads, at a minimum. The primary interfaces are defined in the Spacecraft/MOC ICD.

ETE objectives and test results will be maintained via a Spacecraft to Ground Interface Matrix (SGIM). The SGIM provides a detailed list of the individual interface items that need to be tested between the MOC and the GLAST observatory to establish compatibility between these two systems. The GLAST Ground System Engineer is responsible for maintaining this matrix.

4.4.5 Science Tool Verification

The GLAST User's Committee (GUC) will conduct peer reviews of the science tools and algorithms being used on the GLAST project. The GUC will help to ensure that the design and functionality of the tools meet the science community's needs. The GUC provides the Project with an independent assessment of the science tools being developed for use by the science community.

4.5 Discrepancy Management

Discrepancy management refers to the process to be used to document, prioritize, track, and close out anomalies that are detected in the Ground System. These anomalies may be detected during element development, element-level acceptance testing, ground system testing, or operations activities. This section will briefly describe the discrepancy management approach to be used by the GLAST Ground System.

At the element level, each element will manage its own discrepancies internally, though the GSOM will have full visibility into the discrepancy system. While no specific discrepancy management approach will be dictated, each approach must provide for the ability to document and prioritize each detected anomaly.

At the Ground System level, discrepancies discovered during testing will be recorded and managed through the Discrepancy Management System that will be developed for the MOC. This system will have categories for discrepancies associated with the Ground Readiness Tests, End-to-End Tests, and R/T tests. The Discrepancy Management System will be based on the Spacecraft Emergency Response System (SERS), which is a Swift heritage system

The Ground System Discrepancy Review Board (DRB) will disposition all DR's, allocating the proper criticality based on the criticality of the associated functionality. Problems that are considered essential to supporting launch and early orbit activation will be categorized as "launch critical" and will thus receive the appropriate level of priority by the development team. The DRB will be chaired by the Ground System Engineer and will be made up of representatives from each of the Ground System elements and appropriate operations personnel. The GRTT and DRB will work closely together, but essentially will serve two different purposes: the GRTT will primarily plan and analyze tests, while the DRB will evaluate and track individual system anomalies and associated repairs.

APPENDIX A – QUALITY RECORDS LIST

The Quality Records List (QRL) for the GLAST ground system implementation effort is provided below. The Quality Record Custodian for all ground system Quality Records (QR) listed here is the Ground System/Operations Manager, Ken Lehtonen/GSFC Code 580, except for the Ground System Discrepancy Reports. The Ground System Test Lead is the QR Custodian for this QR. The QR Custodian does not necessarily develop or generate the QR, but does ensure that up-to-date, approved versions are regularly made available on the appropriate Web site. The purpose of the QRs is to document the plans for implementing the Ground System (e.g., GSRD and ICDs) and the results of the actual implementation effort (e.g., Delivery Letters and Discrepancy Reports).

Located at GLAST Project Web site: URL http://glast.gsfc.nasa.gov/project/gsmo/

- ° GLAST Ground System Project Plan
- ° GLAST Operations Concept Document
- ° Ground System Requirements Document
- ° Product Development and Management Plan
- ° Spacecraft/Ground ICD
- ° Spacecraft/SN ICD

Located at Ground System Web site: URL http://glast.gsfc.nasa.gov/project/gsmo/

- ° GLAST Ground System Schedule
- ° Project Service Level Agreement (PSLA)
- ° Ground System ICDs
- ° Ground System Test Plan
- ° Ground System Requirements Validation Matrix
- ° Ground Readiness Test Reports
- ° Ground System Delivery Packages
- ° GLAST Ground System Discrepancy Reports

Hard Copy Access Only:
- ° IT Security Plan
- ° IT Contingency Plan
- ° IT Risk Management Plan

APPENDIX B – ACRONYM LIST

AL	Alabama
ASDC	ASI Science Data Center
ASI	*Agenzia Spaziale Italiana* (Italian Space Agency)
ASINET	ASI Network
AZ	Arizona
BAM	Burst Alert Message
BAP	Burst Alert Processor
CCB	Configuration Control Board
CCR	Configuration Change Request
CDR	Critical Design Review
CDRL	Contract Documentation Requirements List
CMS	Configuration Management System
CSOC	Consolidated Spacecraft Operations Contract
CTV	Compatibility Test Van
DAS	Demand Access Service
DFCD	Data Format Control Document
DPF	Data Processing Facility
DPR	Design Peer Review
DDPR	Detailed or Delta Design Peer Review
DR	Discrepancy Report
DRB	Discrepancy Review Board
DSMC	Data Services Management Center
ETE	End-To-End
F&PR	Functional and Performance Requirements
FITS	Flexible Image Transport System
FoM	Figure of Merit
FOT	Flight Operations Team
GBM	GLAST Burst Monitor
GCN	GRB Coordinates Network
GFEP	GLAST Front-End Processor
GI	Guest Investigator
GIOC	GBM Instrument Operations Center
GLAST	Gamma Ray Large Area Space Telescope
GOWG	GLAST Ground Operations Working Group
GRB	Gamma-Ray Burst
GRT	Ground Readiness Test
GRTT	Ground Readiness Test Team
GSDR	Ground System Design Review
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GSOM	Ground System/Operations Manager
GSRD	Ground System Requirements Document
GSRM	Ground System Risk Manager
GSRVM	Ground System Requirements Validation Matrix
GSSC	GLAST Science Support Center
GUC	GLAST Users' Committee
HEASARC	High Energy Astrophysics Science Archive Research Center

I&T	Integration & Test
ICD	Interface Control Document
IOC	Instrument Operations Center
IOT	Instrument Operations Team
IOWG	Instrument Operations Working Group
IPO	Instrument Program Office
IT	Information Technology
ITOS	Integrated Test and Operations System
ISO	International Organization for Standards
ISOC	Instrument Science and Operations Center
JSC	Johnson Space Center
KSC	Kennedy Space Center
LAT	Large Area Telescope
L&EO	Launch & Early Orbit
LD	L&EO Director
LISOC	LAT Instrument and Science Operations Center
MAR	Mission Assurance Requirements
MIDEX	Medium-class Explorer
MMFD	Multi-Mission Flight Dynamics
MOA	Mission Operations Agreement
MOC	Mission Operations Center
MOM	Mission Operations Manager
MOMS	Mission Operations and Mission Services
MOR	Mission Operations Review
MOT	Mission Operations Team
MPE	Max Planck Institute for Extraterrestrial Physics
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NCC	Network Control Center
NISN	NASA Integrated Services Network
NORAD	North American Air Defense Command
NPG	NASA Procedures and Guidelines
NSSTC	National Space Science and Technology Center
OCD	Operations Concept Document
ORR	Operations Readiness Review
PDB	Project Data Base
PDR	Preliminary Design Review
PI	Principal Investigator
PSLA	Project Service Level Agreement
PSS	Portable Spacecraft Simulator
QR	Quality Record
QRL	Quality Record List
RF	Radio Frequency
RFA	Request for Action
RID	Risk Information Database
RT	Real-Time
SAI	Spectrum Astro Inc.
SAS	Science Analysis Software

Mike Rackley
Ground System/Ops Manager
GSFC

Howard Dew
Ground Sys Engineer
GSFC

Dave Harmon
QA Engineer
Tybrin

Billy Frederle
USN Support
USN

S/C	Spacecraft
SERS	Spacecraft Emergency Response System
SGIM	Spacecraft to Ground Interface Matrix
SMEX	Small Explorer Program
SN	Space Network
SOC	Simulations Ops Center
SOMO	Space Operations Management Office
SRD	System Requirements Document
SRR	System Requirements Review
SNAS	Space Network Access System
SSR	Solid State Recorder
STDN	Spacecraft Tracking and Data Network
STOL	Spacecraft Test and Operation Language
SWSI	Space Network (SN) Web Services Interface
T&C	Telemetry and Command
TBD	To Be Determined
TCP/IP	Transfer Control Protocol/Internet Protocol
TCS	Thermal Control System
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TIM	Technical Interchange Meeting
TLE	Two-Line Element
TLM	Telemetry
ToO	Target of Opportunity
UAH	University of Alabama in Huntsville
URL	Uniform Resource Locator
U.S.	United States of America
USN	Universal Space Network
VC	Virtual Channel
WSC	White Sands Complex
WWW	World Wide Web

Ross Cox/ASRC
Ernest Chevari/ASRC
Bruce Wagner/ITMI

Beth Humphrey
Test Lead
GSFC

Leslie Ambrose
CSOC Support
GSFC

Bob Sodano
Mission Director
GSFC

Stan Rubin
NISN Support
GSFC

Marty Woodard
FD Engineer

Karl Davis
Observatory Ops Lead
Spectrum Astro

Dennis Small
MOC Lead
GSFC

Bill Craig
LAT IOC/LOF Lead

Richard Dubois
LAT IOC/SAS Lead
SLAC

Bill Paciesas
GBM IOC Lead
UAH

Jay Norris
GSSC Lead
GSFC

Scott Barthelmy
GCN Lead
GSFC

Doug Spiegel/Omitron
MOC Manager

Michael Decroix
HEASARC Lead

Robert Preece/UAH
Implementation Lead

David Band/GSFC
Science Lead

John Nagy/Omitron
FOT Lead

Robin Corbet/GSFC
Operations Lead

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